

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
18 December 2003 (18.12.2003)

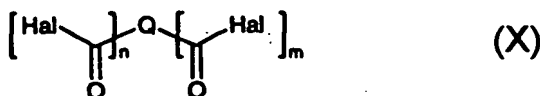
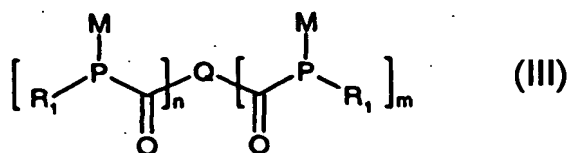
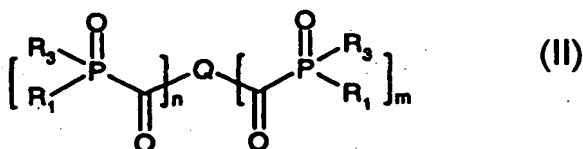
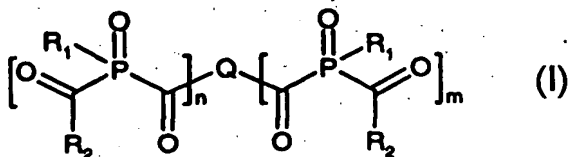
PCT

(10) International Publication Number
WO 03/104245 A1

- (51) International Patent Classification⁷: C07F 9/53, HUG, Gebhard [CH/CH]; Buchenweg 30, CH-4310 Rheinfelden (CH).
9/6568, 9/28, C08F 2/50, G03F 7/029
- (21) International Application Number: PCT/EP03/05801
- (22) International Filing Date: 3 June 2003 (03.06.2003)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 02405473 11 June 2002 (11.06.2002) EP
- (71) Applicant (for all designated States except US): CIBA SPECIALTY CHEMICALS HOLDING INC. [CH/CH]; Klybeckstrasse 141, CH-4057 Basel (CH).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): WOLF, Jean-Pierre [CH/CH]; Chilmetweg 6, CH-4464 Maisprach (CH).
- (74) Common Representative: CIBA SPECIALTY CHEMICALS HOLDING INC.; Klybeckstrasse 141, CH-4057 Basel (CH).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,

[Continued on next page]

(54) Title: MULTIMER FORMS OF MONO- AND BIS-ACYLPHOSPHINE OXIDES



(57) Abstract: The invention relates to dimer and multimer forms of BAPO compounds of the formula (I) dimer and multimer forms of MAPO compounds of the formula (II) wherein R_1 , R_2 , and R_3 independently of one another are unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl; Q is a di-tri or tetravalent arylene residue; n is 1-4, m is 0-2, n+m is 2, 3 or 4, with the proviso, that R_1 and R_3 are different from each other. The invention further relates to a process for the preparation of dimer or multimer forms of BAPO compounds of the formula (I) and of dimer or multimer forms of MAPO compounds of the formula (II), characterized in the (n + m) equivalents of a dimetalated-phosphine $R_1P(M)_2$ is reacted with one equivalent of a di- or polycarboxylic acid halogenide to form an intermediate of the formula III the intermediate is then reacted either with (n + m) equivalents of a further carboxylic acid halogenide (R_2 -CO-Hal) or with a halogenide R_3 -Hal, the reaction products are then oxidized to form phosphine oxides of the formula I or II.



ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

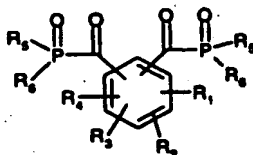
Published:

— *with international search report*

MULTIMER FORMS OF MONO- AND BIS-ACYLPHOSPHINE OXIDES

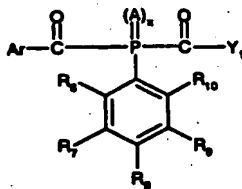
The present invention relates to new dimer and multimer forms of monoacylphosphine oxides (MAPO), bisacylphosphine oxides (BAPO), to new cyclic forms of bisacyl phosphine oxides (BAPO), to a process for their preparation and to new acylphosphine compounds obtained as intermediates in said process.

The preparation of dimer forms of monoacylphosphine oxides of the general formula



has been described in the European Patent Publication EP-A 0 601 413. Said process is characterized in that an arene-bisacyl chloride is reacted with e.g. an alkoxy-diphenylphosphine. The compounds obtained are due to the alkoxy-diphenylphosphine reactant symmetric dimer forms of monoacylphosphine oxides, i.e. the residue $R_5=R_6$. Concerning asymmetric forms one of the residues R_5 or R_6 must be an alkoxy group.

The US Patent Publication 2001/0031898 describes the preparation of monomer forms of bisacylphosphine oxides

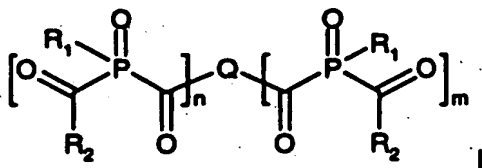


by reacting an acyl halide $Ar-CO-X$ with a dimetalated phosphine $RP(M)_2$ and subsequent reaction of the product obtained with an acyl halide. Dimer forms of BAPO compounds are encompassed by the general definition of the compounds described in US Patent Publication 2001/0031898 but they have not been actually and explicitly disclosed in this patent publication, nor the preparation thereof has been exemplified.

There is still a need to find a method for preparing both, dimer and multimer symmetric and asymmetric forms of BAPO and MAPO compounds as well as cyclic forms of BAPO compounds, whereby said method should, in case of MAPO compounds, have a broad latitude in the choice of substituents on the phosphor atom.

- 2 -

In one aspect the invention relates to dimer and multimer forms of BAPO compounds of the formula I



wherein

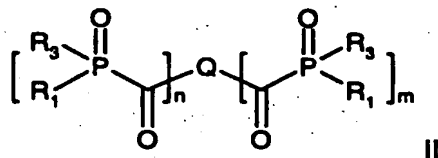
R_1 is unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

R_2 is unsubstituted or substituted C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

Q is a di-tri or tetravalent arylene residue;

n is 1-4, m is 0-2, $n+m$ is 2, 3 or 4.

The invention further relates to dimer and multimer forms of MAPO compounds of the formula II



wherein

R_1 and R_3 independently of one another are unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

Q is a di-tri or tetravalent arylene residue;

n is 1-4, m is 0-2, $n+m$ is 2, 3 or 4;

with the proviso, that R_1 and R_3 are different from each other.

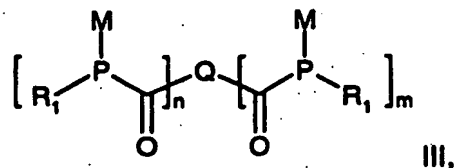
The invention further relates to a process for the preparation of dimer or multimer forms of BAPO compounds of the formula I and of dimer or multimer forms of MAPO compounds of the formula II,

characterized in that $(n + m)$ equivalents of a dimetalated-phosphine $\text{R}_1\text{P}(\text{M})_2$ are reacted

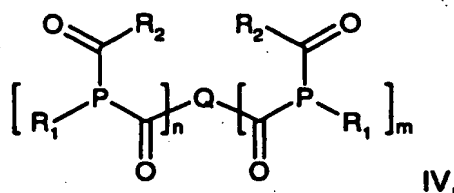
with one equivalent of a di- or polycarboxylic acid halogenide $\left[\begin{array}{c} \text{Hal} \\ \diagup \\ \text{C} \\ \diagdown \\ \text{O}=\text{C} \end{array} \right]_n \text{Q} \left[\begin{array}{c} \text{O}=\text{C} \\ \diagup \\ \text{C} \\ \diagdown \\ \text{Hal} \end{array} \right]_m$

to form an intermediate of the formula III

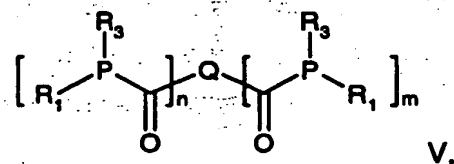
- 3 -



the intermediate is then reacted either with $(n + m)$ equivalents of a further carboxylic acid halogenide ($\text{R}_2\text{-CO-Hal}$) to form dimer or multimer forms of bisacylphosphine-intermediates of the formula IV



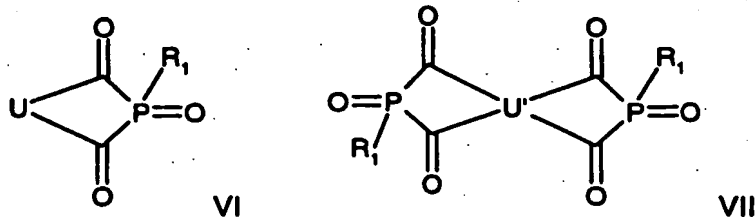
or with a halogenide $\text{R}_3\text{-Hal}$ to form dimer or multimer forms of monoacylphosphine intermediates of the formula V



said phosphines IV or V are then oxidized to form phosphine oxides of the formula I or II, wherein M is Li, Na or K and R_1 , R_2 and R_3 , Q, n and m are as defined above.

The intermediate compounds of the formula III are novel and are also part of the invention. Thus, the invention further relates to compounds of the formula III as defined above. The compounds of the formula III are identified by ^{31}P -NMR spectroscopy and are stable in solution under inert gas at room temperature for a number of weeks.

The invention further relates to cyclic forms of BAPO compounds of the formula VI and VII



wherein

R_1 is unsubstituted or substituted $\text{C}_1\text{-C}_{12}$ alkyl, benzyl, $\text{C}_1\text{-C}_{12}$ alkoxy, $\text{C}_3\text{-C}_6$ cycloalkyl or $\text{C}_5\text{-C}_{14}$ aryl;

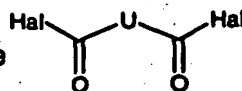
U is a divalent arylene residue and U' is a tetravalent arylene residue.

- 4 -

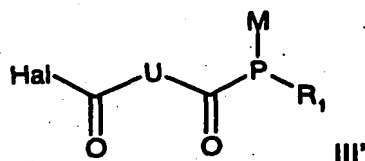
The invention further relates to a process for the preparation of cyclic forms of BAPO compounds of the formula VI

characterized in that one equivalent of a dimetalated-phosphine $R_1P(M)_2$ is reacted with one

equivalent of a dicarboxylic acid halogenide



to form an intermediate of the formula III'

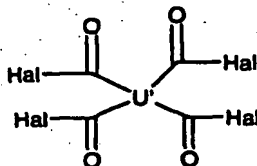


said intermediate cyclizes and is then oxidized to form phosphine oxides of the formula VI wherein R_1 , M and U are as defined above.

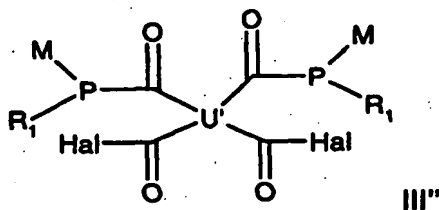
The invention further relates to a process for the preparation of cyclic forms of BAPO compounds of the formula VII

characterized in that two equivalent of a dimetalated-phosphine $R_1P(M)_2$ are reacted with one

equivalent of a tetracarboxylic acid halogenide



to form an intermediate of the formula III''



said intermediate cyclizes and is then oxidized to form phosphine oxides of the formula VII wherein R_1 , M and U' are as defined above.

Preference is given to using compounds of the formula I or II in which n is 1 and m is 1.

Definitions

C_1 - C_{12} alkyl is linear or branched and is, for example, C_1 - C_{12} alkyl, C_1 - C_8 alkyl, C_1 - C_6 alkyl or C_1 - C_4 alkyl. Examples are methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, pentyl, hexyl, heptyl, 2,4,4-trimethylpentyl, 2-ethylhexyl, octyl, nonyl, decyl, undecyl, dodecyl. The alkyl groups may be interrupted once or more than once by O, S or N(C_1 - C_{12} alkyl). If the radicals are interrupted by two or more O, S or N(C_1 - C_{12} alkyl) then the O atoms, S atoms or N(C_1 - C_{12} alkyl) groups are in each case separated from one another by at least one methylene group. The O atoms, S atoms or N(C_1 - C_{12} alkyl) groups are thus not directly consecutive. For example, structural units such as $-CH_2-O-CH_3$, $-CH_2CH_2-O-CH_2CH_3$, $-[CH_2CH_2O]_z-CH_3$, where $z = 1$ to 9, $-(CH_2CH_2O)_7CH_2CH_3$, $-CH_2-CH(CH_3)-O-CH_2-CH_2CH_3$, $-CH_2-CH(CH_3)-O-CH_2-CH_3$, $-CH_2SCH_3$ or $-CH_2-N(CH_3)_2$ arise.

The alkyl groups may be mono- or polysubstituted by C_1 - C_{12} alkyl; C_1 - C_{12} alkoxy, $-S-C_1$ - C_{12} alkyl, phenyl, phenoxy, $-COOC_1$ - C_{12} alkyl, $-COO-C_5$ - C_{14} aryl or CN.

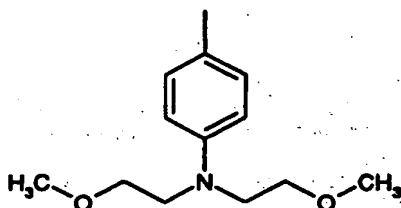
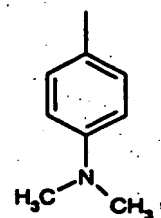
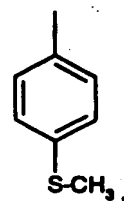
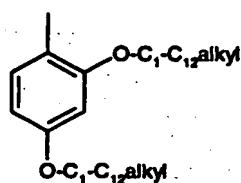
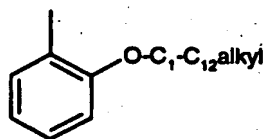
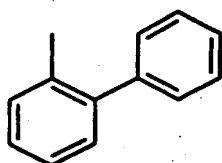
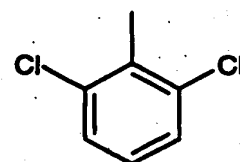
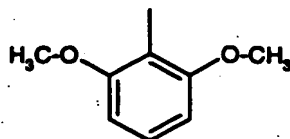
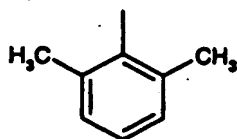
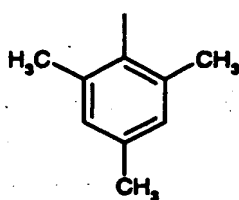
As used herein, the term " C_1 - C_{12} alkoxy" refers to a group $O-C_1$ - C_{12} alkyl, wherein the alkyl radical is as described above.

Examples of C_3 - C_6 cycloalkyl groups are cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl. The C_3 - C_6 cycloalkyl groups may be substituted by C_1 - C_{12} alkyl, C_1 - C_{12} alkoxy, $-S-C_1$ - C_{12} alkyl, phenyl, phenoxy, $-COOC_1$ - C_{12} alkyl, $-COO-C_5$ - C_{14} aryl or CN. Examples are 2,4,6-trimethylcyclohexyl, 2,6-dimethylcyclohexyl and 2,6-dimethoxycyclohexyl.

C_5 - C_{14} aryl is phenyl, naphthyl, biphenyl, anthracyl and the like.

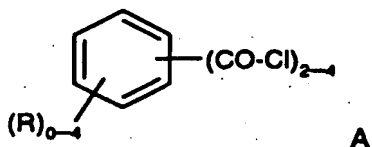
The aryl radicals may be mono or polysubstituted by halogen, phenyl, C_1 - C_{12} alkyl and/or C_1 - C_{12} alkoxy, $-S-C_1$ - C_{12} alkyl, CF_3 , Cl, $-N(C_1$ - C_{12} alkyl) $_2$ or $-N(C_1$ - C_{12} alkyl interrupted by O) $_2$.

Examples are:



Q is a di-tri or tetravalent arylene residue derived from the following di or polycarboxylic acid halogenides, preferably chlorides.

Compounds of the formula A



wherein

R is C₁-C₁₂alkyl, C₁-C₁₂alkoxy, C₁-C₁₂alkylthio, C₅-C₁₄aryl, O-C₅-C₁₄aryl, halogen, NH(C₁-C₁₂alkyl), N(C₁-C₁₂alkyl)₂, C(O)O(C₁-C₁₂alkyl), CO-NH(C₁-C₁₂alkyl), CO-N(C₁-C₁₂alkyl)₂ or CF₃

Commercial compounds of the formula A are:

Phthalic acid and derivatives thereof such as, for example, tetrafluoro- or tetrachloro phthalic acid, 3-fluorophthalic acid, 4-(trifluoromethyl)phthalic acid, 4-chloro- or 4,5-dichlorophthalic acid, 4-methylphthalic acid;

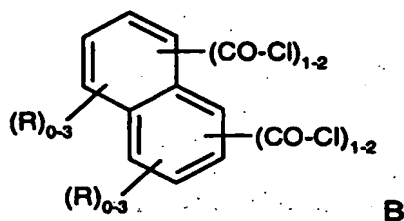
Hemimellitic-, trimellitic- and pyromellitic acid;

Isophthalic acid and derivatives thereof such as, for example, tetrafluoroisophthalic acid, 4-bromoisophthalic acid, 4-hydroxy- or 5-hydroxyisophthalic acid, 5-aminoisophthalic acid;

Trimesic acid, 5-methyl-1,3-benzenedicarboxylic acid;

Terephthalic acid and derivatives thereof such as, for example, tetrafluoro- or tetrachloroterephthalic acid, 2-bromoterephthalic acid, 2-aminoterephthalic acid, 2,5-dimethylterephthalic acid, 2,5-dichloro- or 2,5-dibromoterephthalic acid.

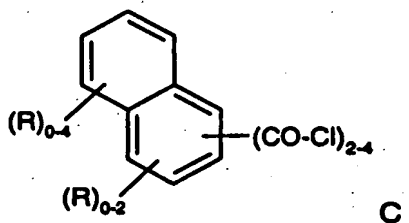
Compounds of the formula B



wherein R is as defined in formula A.

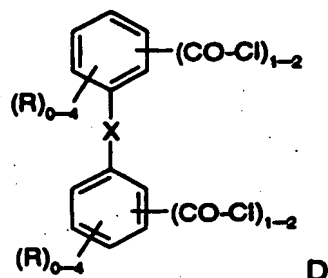
Commercial compounds of the formula B are 1,4,5,8-naphthalene tetracarboxylic acid or 1,4,5,8-naphthalene tetracarboxylic acid hydrate.

Compounds of the formula C



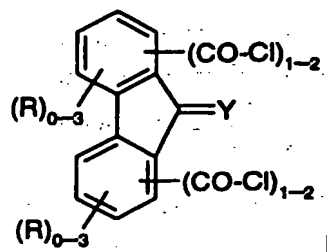
wherein R is as defined in formula A.

Commercial compounds of the formula C are 2,3-naphthalenedicarboxylic acid or 1,4-naphthalene dicarboxylic acid.

Compounds of the formula D

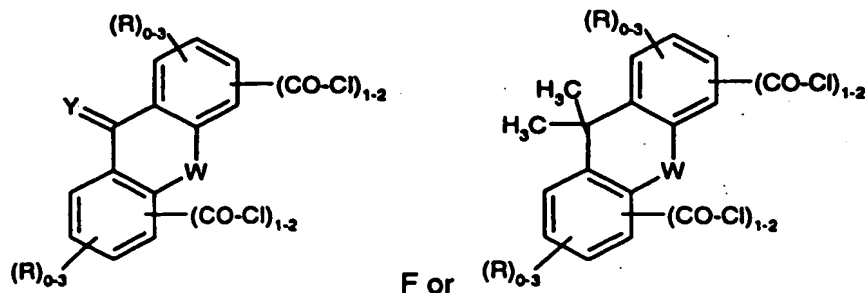
wherein R is as defined in formula A and X is a bond, -O-, -S-, methylene, -CH(CH₃)-, -C(CH₃)₂-, -C(CF₃)₂-, -C(O)-, -S(O)- or -S(O)₂-.

Commercial compounds of the formula D are 3,3',4,4'-benzophenonetetracarboxylic acid, 2,3,2'-biphenyltricarboxylic acid or 4,4'-(hexafluoroisopropylidene)phthalic acid.

Compounds of the formula E

wherein R is as defined in formula A and Y is H₂, O, S or CH₂.

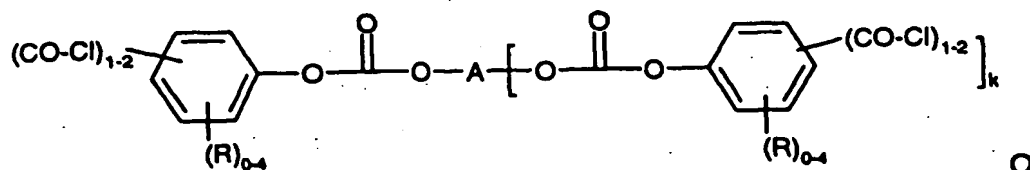
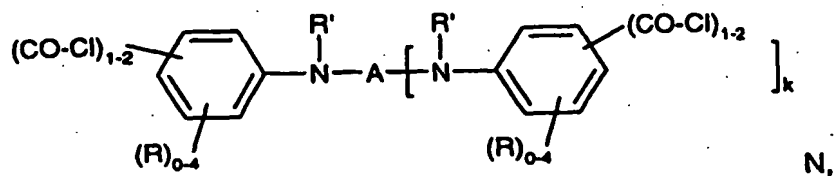
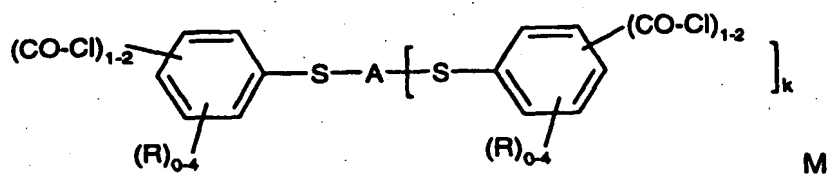
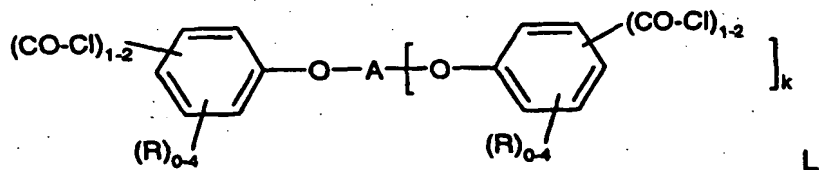
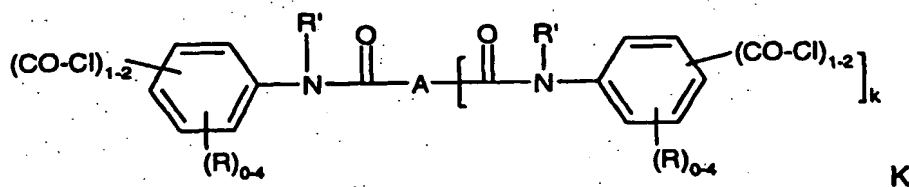
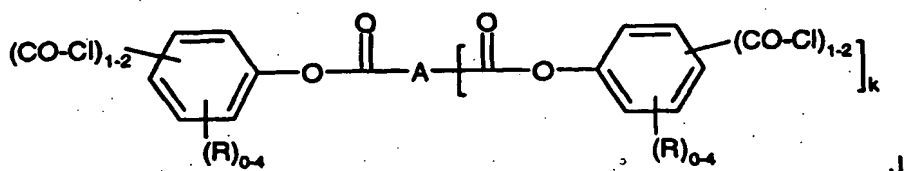
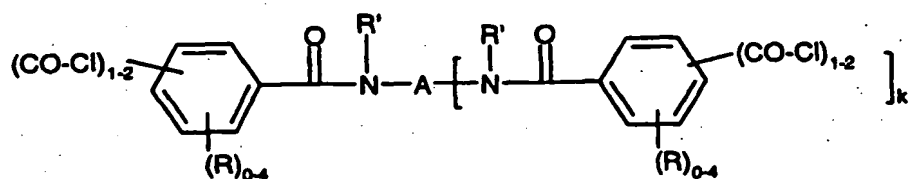
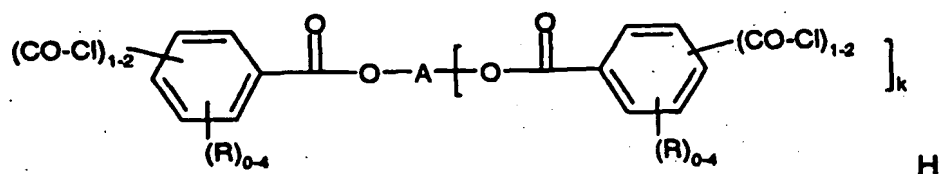
Commercially available is 9-fluorenone-2,7-dicarboxylic acid

Compounds of the formula F or G

wherein R and Y are as defined above, and W is O, S, CH₂ or N(C₁-C₁₂alkyl).

Commercially available is 2,7-di-tert-butyl-9,9-dimethyl-4,5-xanthenedicarboxylic acid.

Compounds of the formula H, I, J, K, L, M, N or O.



wherein

k is 1-3,

R is as defined above,

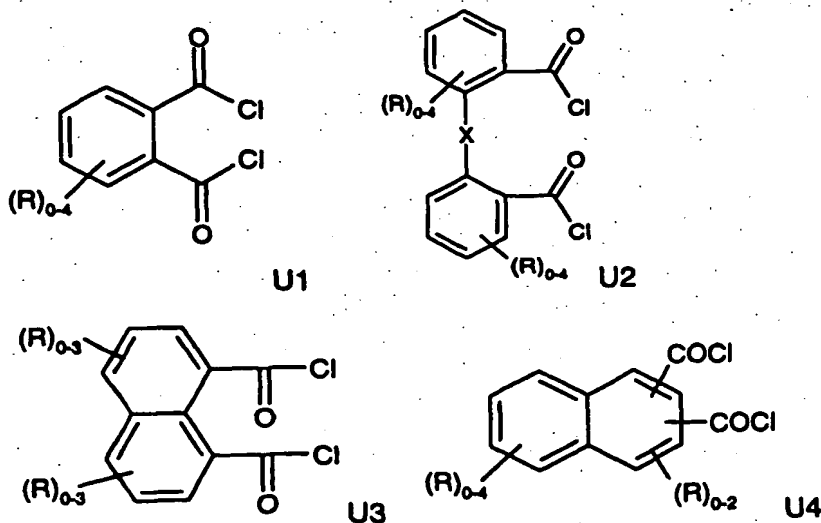
R' is hydrogen, phenyl, C₁-C₁₂ alkyl or C₃-C₆ cycloalkyl,

A is selected from C₅-C₁₄ arylene, C₃-C₆ cycloalkylene or bicycloalkylene, linear or branched C₂-C₂₄ alkylene optionally interrupted once or more than once by non-consecutive -O- or -S- atoms or by groups selected from -CO-, -COO-, -OCO-, -O-COO-, phenylene, C₅-C₁₄ arylene, C₃-C₆ cycloalkylene, -CH=CH-, bicycloalkylene, biphenylene, -Si(CH₃)₂-, -Si(CH₃)₂-O-Si(CH₃)₂- or -CF₂-.

The group A may be substituted by C₁-C₁₂ alkyl, C₁-C₁₂ alkoxy, -S-C₁-C₁₂ alkyl, phenyl, phenoxy, -O-COC₁-C₁₂ alkyl, -O-COC₅-C₁₄ aryl, -COOC₁-C₁₂ alkyl, -COO-C₅-C₁₄ aryl, CN, CF₃, F or Cl.

Concerning cyclic forms of BAPO compounds of the formula VI

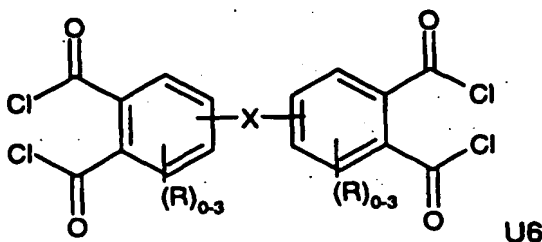
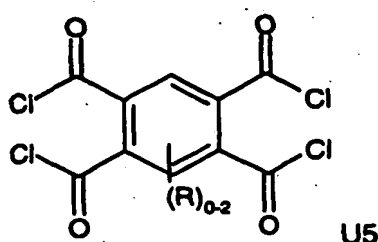
U is a divalent arylene residue derived from the following dicarboxylic acid halogenides, preferably chlorides, U1-U4



wherein R and X are as defined above.

Concerning cyclic forms of BAPO compounds of the formula VII

U' is a tetravalent arylene residue derived from the following tetracarboxylic acid halogenides, preferably chlorides, U5 and U6



The process starting compounds:

The preparation of the metalated phosphines $R_1P(M)_2$ can, for example, be carried out by reacting suitable phosphorus halides $R_1P(Hal)_2$ (preparation of which is known and disclosed, for example, by W. Davies in J. Chem. Soc. (1935), 462 and J. Chem. Soc. (1944), 276 with the corresponding alkali metal. Suitable as metal (M) are lithium, sodium or potassium. Lithium is preferred. The use of mixtures of these metals is also possible. 4 to 8 molar equivalents of the alkaline metal are advantageously used. The reaction is advantageously carried out in a solvent. In particular, as solvents, it is possible to use ethers which are liquid at atmospheric pressure and room temperature. Examples are dimethyl ether, diethyl ether, methyl propyl ether, 1,2-dimethoxyethane, bis(2-methoxyethyl) ether, dioxane or tetrahydrofuran. Preference is given to using tetrahydrofuran. The reaction temperatures are advantageously -60°C to $+120^\circ\text{C}$.

Another conceivable method for the preparation of metalated phosphines is, for example, the reaction of suitable phosphines $R_1P(H)_2$ with the corresponding alkali metal hydride or an alkyllithium compound with the exclusion of air in an inert solvent at temperatures of e.g. -80°C to $+120^\circ\text{C}$. Advantageously, 2 to 4 mol equivalents of the alkali metal hydrides or alkyllithium compound are used. Suitable solvents are e.g. ethers as described above, or inert solvents, such as alkanes, cycloalkanes, or aromatic solvents such as toluene, xylene, mesitylene.

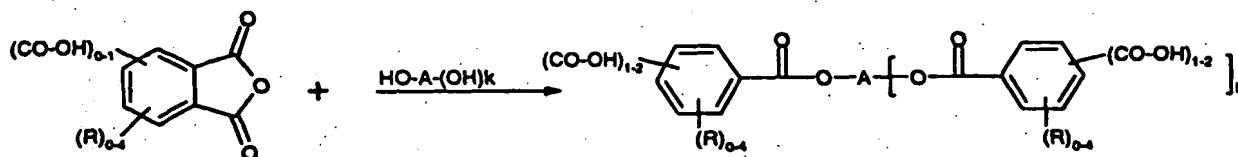
Suitable aryl phosphines can be prepared by reduction of the corresponding aryldichlorophosphines $[Ar-P-Cl_2]$, arylphosphonic esters $[Ar-P-O(OR')_2]$ and arylphosphonous esters $[Ar-P(OR')_2]$ using $LiAlH_4$; $SiHCl_3$; Ph_2SiH_2 (Ph = phenyl); a) LiH, b) H_2O ;

a) Li/tetrahydrofuran, b) H_2O or a) Na/toluene, b) H_2O . These methods are described, for example, in US 6020528 (col. 5-6). Hydrogenations using $LiAlH_4$ are given, for example, in Helv. Chim. Acta 1966, No. 96, 842.

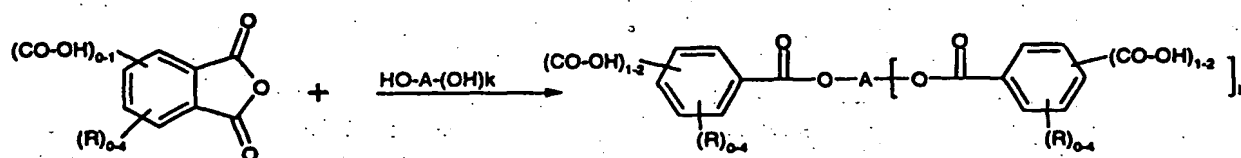
The di- or poly carboxylic acid halogenides used as starting material are known substances, some of which are available. Examples are listed above.

Carboxylic acid chlorides which are not commercially available may be prepared starting from the corresponding carboxylic acids using known reactions. The corresponding carboxylic acids may be prepared as follows.

Compounds H: by reaction of an anhydride with a di-, tri- or tetrafunctional alcohol.

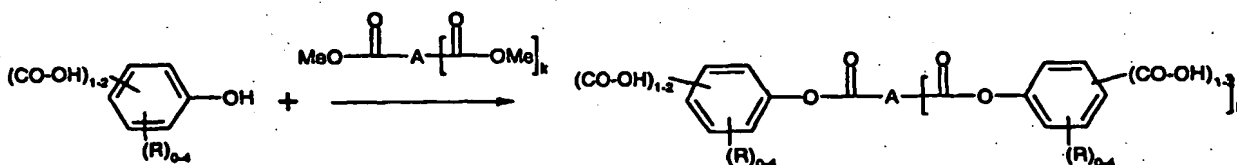


Compound I: by reaction of an anhydride with a di-, tri- or tetrafunctional amine.



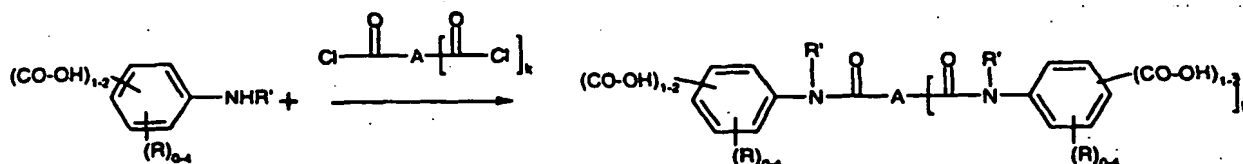
Suitable anhydrides are, for example, phthalic anhydride, hemimellitic anhydride, trimellitic anhydride, tetrafluorophthalic anhydride or 4,5-dichlorophthalic anhydride.

Compound J: by transesterification of a hydroxy carboxylic acid with a di-, tri- or tetrafunctional ester.



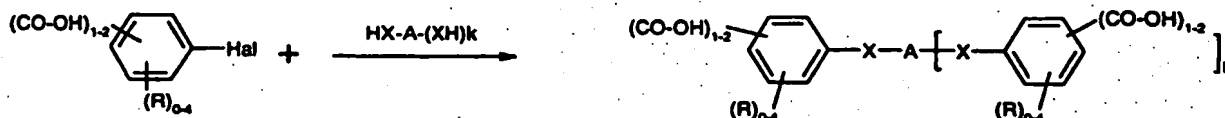
Suitable hydroxy carboxylic acids are, for example, 4-hydroxyphthalic acid, 5-hydroxy-isophthalic acid, 3-hydroxy- or 4-hydroxybenzoic acid or salicylic acid.

Compound K: by reaction of an aminocarboxylic acid with a di-, tri- or tetrafunctional acid chloride



Suitable aminocarboxylic acids are, for example, 3-amino- or 4-aminophthalic acid, 5-aminoisophthalic acid, 2-aminoterephthalic acid, antranilic acid, 3-amino- or 4-aminobenzoic acid.

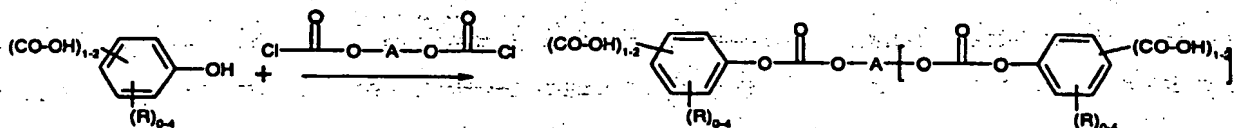
Compounds L, M or N: by reaction of a halogen substituted carboxylic acids with a di-, tri- or tetrafunctional alcohol, amine or thiol



X = O, S, NR'

Suitable halogen substituted carboxylic acids are, for example, 3-fluoro- or 4-chlorophthalic acid, 2-fluoroisophthalic acid, 2-fluoro- or 4-fluorobenzoic acid or 4-chlorobenzoic acid.

Compound O: by reaction of a hydroxy carboxylic acid with a di-, tri- or tetrafunctional chloroformate.



Suitable hydroxy carboxylic acids are, for example, 4-hydroxyphthalic acid, 5-hydroxyisophthalic acid, 3-hydroxy- or 4-hydroxybenzoic acid, salicylic acid.

Cyclic forms of Bapo compounds may be prepared starting from the following dicarboxylic acid chlorides of the formula U1: phthalic acid, tetrafluorophthalic acid, 4,5-dichlorophthalic acid, 4-hydroxy-, 3-fluoro- or 4-chloro phthalic acid; of the formula U2 2,2-oxydibenzoic acid or diphenic acid; of the formula U3 naphthalene-1,8-dicarboxylic acid; of the formula U4 2,3-naphthalene dicarboxylic acid; or starting from the following tetracarboxylic acids: 3,3',4,4'-benzophenone tetracarboxylic acid or 4,4'-(hexafluoroisopropylidene)diphthalic acid.

Inventive process

The process starts by reacting a carboxylic acid halogenide with a metalated phosphine preferably in an inert solvents such as THF, dioxane or diethylether at a temperature from -20 to 80°C.

An important feature of the process for preparing dimer or multimer forms of BAPO or MAPO compounds comprises the control of the mole ratio of metalated phosphine to di- or polycarboxylic acid chloride. It is desirable that about one equivalent of metalated phosphine groups be available per equivalent of acid chloride groups. The carboxylic acid chloride is preferably dropped into the phosphine in order to maintain an excess of the phosphine. Using about 0.5 equivalents of metalated phosphine groups per equivalent of acid chloride groups results in cyclic bisacylphosphine oxides.

The reaction between the di- or polycarboxylic acid chloride and the metalated phosphine produces an intermediate having the structural formula III.

To prepare MAPO compounds the intermediate is treated with an alkyl or aryl halogenide resulting in P-alkylation of the phosphine. The alkylating agent is added slowly. The reaction is preferably carried out in the same solvent and temperature range as in the first reaction step providing the intermediate.

To prepare BAPO compounds the intermediate is treated with another carboxylic acid halogenide resulting in P-acylation of the phosphine. The acylating agent is added slowly. The reaction is carried out in the same solvent and temperature range as in the first reaction step providing the intermediate.

The oxidation of the phosphine is carried out using oxidizing agents customary in the art. Suitable oxidizing agents are, for example, hydrogen peroxide, air or pure oxygen.

Use

The MAPO and BAPO compounds of the formula I and II as well as the cyclic BAPO compounds of the formula VI or VII can be used as photoinitiators for the photopolymerization of ethylenically unsaturated compounds or mixtures which comprise such compounds. This use can also take place in combination with other photoinitiators and/or other additives.

Thus, the invention also relates to a photopolymerizable composition comprising

- (a) at least one ethylenically unsaturated photopolymerizable compound, and
- (b) as photoinitiator, at least one compound of the formula I, II, VI or VII as defined above.

The unsaturated compounds can contain one or more olefinic double bonds. They can be of low molecular weight (monomeric) or relatively high molecular weight (oligomeric). Examples of monomers with a double bond are alkyl or hydroxyalkyl acrylates or methacrylates, for example methyl acrylate, ethyl acrylate, butyl acrylate, 2-ethylhexyl acrylate or 2-hydroxyethyl acrylate, isobornyl acrylate, methyl methacrylate or ethyl methacrylate. Also of interest are silicon- or fluorine-modified resins, e.g. silicone acrylates. Further examples are acrylonitrile, acrylamide, methacrylamide, N-substituted (meth)acrylamides, vinyl esters, such as vinyl acetate, vinyl ethers, such as isobutyl vinyl ether, styrene, alkyl- and halostyrenes, N-vinylpyrrolidone, vinyl chloride or vinylidene chloride.

Examples of monomers having two or more double bonds are ethylene glycol diacrylate, propylene glycol diacrylate, neopentyl glycol diacrylate, hexamethylene glycol diacrylate or bisphenol A diacrylate, 4,4'-bis(2-acryloyloxyethoxy)diphenylpropane, trimethylolpropane triacrylate, pentaerythritol triacrylate or tetraacrylate, vinyl acrylate, divinylbenzene, divinyl succinate, diallyl phthalate, triallyl phosphate, triallyl isocyanurate or tris(2-acryloylethyl) isocyanurate.

Examples of higher molecular weight (oligomeric) polyunsaturated compounds are acrylicized epoxy resins, polyurethanes, polyethers and polyesters which are acrylicized or contain vinyl ether or epoxy groups. Further examples of unsaturated oligomers are unsaturated polyester resins which are mostly prepared from maleic acid, phthalic acid and one or more diols and have molecular weights of from about 500 to 3,000. In addition, it is also possible to use vinyl ether monomers and oligomers, and maleate-terminated oligomers having polyester, polyurethane, polyether, polyvinyl ether and epoxy main chains. In particular, combinations of oligomers which carry vinyl ether groups and polymers as described in WO 90/01512 are highly suitable. However, copolymers of vinyl ether and maleic acid-functionalized monomers are also suitable. Such unsaturated oligomers may also be referred to as prepolymers.

Examples of particularly suitable compounds are esters of ethylenically unsaturated carboxylic acids and polyols or polyepoxides, and polymers containing ethylenically unsaturated groups in the chain or in side-groups, for example unsaturated polyesters, polyamides and polyurethanes and copolymers thereof, alkyd resins, polybutadiene and

butadiene copolymers, polyisoprene and isoprene copolymers, polymers and copolymers containing (meth)acrylic groups in side chains, and mixtures of one or more such polymers.

Examples of unsaturated carboxylic acids are acrylic acid, methacrylic acid, crotonic acid, itaconic acid, cinnamic acid, unsaturated fatty acids such as linolenic acid or oleic acid. Preference is given to acrylic acid and methacrylic acid.

Suitable polyols are aromatic and, in particular, aliphatic and cycloaliphatic polyols. Examples of aromatic polyols are hydroquinone, 4,4'-dihydroxydiphenyl, 2,2-di(4-hydroxyphenyl)propane, and also novolaks and resols. Examples of polyepoxides are those based on said polyols, particularly aromatic polyols and epichlorohydrins. In addition, polymers and copolymers which contain hydroxyl groups in the polymer chain or in side groups, for example polyvinyl alcohol and copolymers thereof or hydroxyalkyl polymethacrylates or copolymers thereof, are also suitable as polyols. Further suitable polyols are oligoesters containing hydroxyl end-groups.

Examples of aliphatic and cycloaliphatic polyols are alkylenediols having, preferably, 2 to 12 carbon atoms, such as ethylene glycol, 1,2- or 1,3-propanediol, 1,2-, 1,3- or 1,4-butanediol, pentanediol, hexanediol, octanediol, dodecanediol, diethylene glycol, triethylene glycol, polyethylene glycols having molecular weights of, preferably, 200 to 1,500, 1,3-cyclopentanediol, 1,2-, 1,3- or 1,4-cyclohexanediol, 1,4-dihydroxymethylcyclohexane, glycerol, tris(β -hydroxyethyl)amine, trimethylolethane, trimethylolpropane, pentaerythritol, dipentaerythritol and sorbitol.

The polyols may be partially or completely esterified using one or different unsaturated carboxylic acids, where the free hydroxyl groups in partial esters may be modified, e.g. etherified or esterified with other carboxylic acids.

Examples of esters are:

trimethylolpropane triacrylate, trimethylolethane triacrylate, trimethylolpropane trimethacrylate, trimethylolethane trimethacrylate, tetramethylene glycol dimethacrylate, triethylene glycol dimethacrylate, tetraethylene glycol diacrylate, pentaerythritol diacrylate, pentaerythritol triacrylate, pentaerythritol tetraacrylate, dipentaerythritol diacrylate, dipentaerythritol triacrylate, dipentaerythritol tetraacrylate, dipentaerythritol pentaacrylate, dipentaerythritol

hexaacrylate, tripentaerythritol octaacrylate, pentaerythritol dimethacrylate, pentaerythritol trimethacrylate, dipentaerythritol dimethacrylate, dipentaerythritol tetramethacrylate, tripentaerythritol octamethacrylate, pentaerythritol diitaconate, dipentaerythritol trisitaconate, dipentaerythritol pentaitaconate, dipentaerythritol hexaitaconate, ethylene glycol diacrylate, 1,3-butanediol diacrylate, 1,3-butanediol dimethacrylate, 1,4-butanediol diitaconate, sorbitol triacrylate, sorbitol tetraacrylate, pentaerythritol-modified triacrylate, sorbitol tetramethacrylate, sorbitol pentaacrylate, sorbitol hexaacrylate, oligoester acrylates and methacrylates, glycerol di- and triacrylate, 1,4-cyclohexane diacrylate, bisacrylates and bismethacrylates of polyethylene glycol having molecular weights of from 200 to 1,500, or mixtures thereof.

Also suitable as component (a) are the amides of identical or different unsaturated carboxylic acids of aromatic, cycloaliphatic and aliphatic polyamines having, preferably, 2 to 6, particularly 2 to 4, amino groups. Examples of such polyamines are ethylenediamine, 1,2- or 1,3-propylenediamine, 1,2-, 1,3- or 1,4-butylenediamine, 1,5-pentylenediamine, 1,6-hexylenediamine, octylenediamine, dodecylenediamine, 1,4-diaminocyclohexane, isophoronediamine, phenylenediamine, bisphenylenediamine, di- β -aminoethyl ether, diethylenetriamine, triethylenetetramine, di(β -aminoethoxy)ethane or di(β -aminopropoxy)ethane. Further suitable polyamines are polymers and copolymers with or without additional amino groups in the side chain and oligoamides containing amino end groups. Examples of such unsaturated amides are: methylenebisacrylamide, 1,6-hexamethylenebisacrylamide, diethylenetriaminetrismethacrylamide, bis(methacrylamidopropoxy)ethane, β -methacrylamidoethyl methacrylate, N[(β -hydroxyethoxy)ethyl]acrylamide.

Suitable unsaturated polyesters and polyamides are derived, for example, from maleic acid and diols or diamines. The maleic acid may be replaced by other dicarboxylic acids. They can be used together with ethylenically unsaturated comonomers, e.g. styrene. The polyesters and polyamides may also be derived from dicarboxylic acids and ethylenically unsaturated diols or diamines, particularly from relatively long chain compounds containing, for example, 6 to 20 carbon atoms. Examples of polyurethanes are those constructed from saturated or unsaturated diisocyanates and unsaturated or saturated diols.

Polybutadiene and polyisoprene and copolymers thereof are known. Suitable comonomers are, for example, olefins, such as ethylene, propene, butene, hexene, (meth)acrylates, acrylonitrile, styrene or vinyl chloride. Polymers containing (meth)acrylate groups in the side

chain are likewise known. These may, for example, be products of the reaction of novolak-based epoxy resins with (meth)acrylic acid, homo- or copolymers of vinyl alcohol or hydroxyalkyl derivatives thereof which have been esterified using (meth)acrylic acid, or homo- and copolymers of (meth)acrylates which have been esterified using hydroxyalkyl(meth)acrylates.

The photopolymerizable compounds may be used on their own or in any desired mixtures. Preference is given to using mixtures of polyol (meth)acrylates.

It is also possible to add binders to the compositions according to the invention; this is particularly advantageous if the photopolymerizable compounds are liquid or viscous substances. The amount of binder may, for example, be 5-95% by weight, preferably 10-90% by weight and particularly 40-90% by weight, based on the total solids. The binder is chosen depending on the field of application and on the properties required therefore, such as the facility for development in aqueous or organic solvent systems, adhesion to substrates and sensitivity to oxygen.

Examples of suitable binders are listed in US Patent Publication 2001/0031898 which publication is included in the present Application by reference.

Apart from the photoinitiator, the photopolymerizable mixtures can also contain various additives such as thermal inhibitors, compounds to increase the storage stability, light protection agents such as for example the following light protection agents listed in US Patent Publication 2001/0031898

2-(2'-Hydroxyphenyl)benzotriazoles, 2-hydroxybenzophenones, esters of unsubstituted or substituted benzoic acids, acrylates, sterically hindered amines, oxalamides, 2-(2-hydroxyphenyl)-1,3,5-triazines, phosphites and phosphonites.

The photopolymerizable mixtures can also contain photosensitizers such as for example the following photosensitizers listed in US Patent Publication 2001/0031898:

Triethanolamine, N-methyldiethanolamine, ethyl p-dimethylaminobenzoate or Michlers ketone, benzophenone, thioxanthone, in particular also isopropylthioxanthone, anthraquinone and 3-acylcoumarin derivatives, terphenyls, styryl ketones, and 3-(aroylmethylene)thiazolines, camphorquinone, but also eosin, rhodamine and erythrosine dyes.

Depending on the intended use, further customary additives are optical brighteners, fillers, pigments, both white and coloured pigments, dyes, antistats, wetting agents or levelling auxiliaries.

The choice of additives depends on the field of application in question and the properties desired for this field. The above-described additives are customary in the art and are accordingly used in amounts customary in the art. Concrete examples for possible additives are given in US Patent Publication 2001/0031898

In certain cases, it may be advantageous to use mixtures of two or more of the photoinitiators according to the invention. It is of course also possible to use mixtures with known photoinitiators.

The photopolymerizable compositions advantageously comprise the photoinitiator in an amount of from 0.05 to 20% by weight, e.g. 0.05 to 15% by weight, preferably 0.1 to 5% by weight, based on the composition. The amount of photoinitiator stated is based on the total of all added photoinitiators if mixtures thereof are used.

The photopolymerizable compositions can be used for various purposes, for example as printing inks, such as screen printing inks, flexographic printing inks or offset printing inks, as clearcoats, as colour coats, as white coats, e.g. for wood or metal, as powder coatings, as paints, inter alia for paper, water, metal or plastic, as daylight-curable coatings for marking buildings and roads, for photographic reproduction processes, for holographic recording materials, for image recording processes or for the production of printing plates which can be developed using organic solvents or aqueous-alkaline media, for the production of masks for screen printing, as dental filling materials, as adhesives, as pressure-sensitive adhesives, as laminating resins, as photoresists, e.g. galvanoresists, etch or permanent resists, both liquid and dry films, as photostructurable dielectrics, and as solder stopping masks for electronic circuits, as resists for the preparation of colour filters for any type of screen or for producing structures in the production process of plasma displays and electroluminescence displays, for the production of optical switches, optical gratings (interference gratings), for the preparation of three-dimensional objects by mass curing (UV curing in transparent moulds) or by the stereolithography process, as is described, for example, in US 4575330, for the preparation of composite materials (e.g. styrenic polyesters which may contain glass fibres and/or other fibres and other auxiliaries) and other thick-layer materials, for the coating or

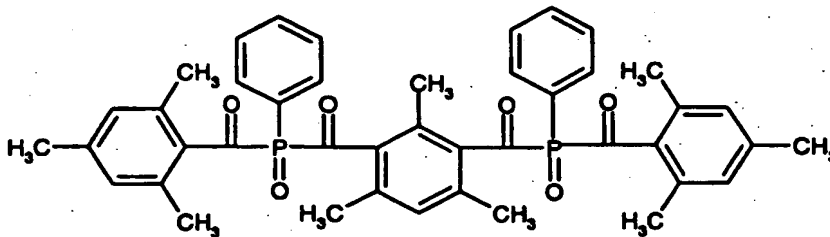
- 20 -

sealing of electronic components or as coatings for optical fibres. The compositions are also suitable for the preparation of optical lenses, e.g. contact lenses and Fresnel lenses, and for the preparation of medical instruments, auxiliaries or implants.

Examples

1. Preparation of dimer bisacylphosphine oxide. (BAPO)

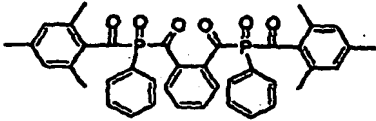
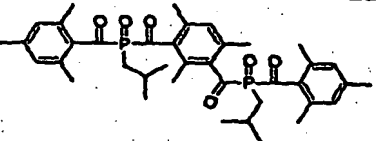
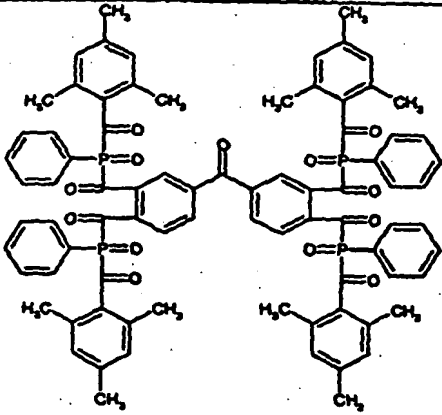
[Phenyl-(2,4,6-trimethyl-benzoyl)-phosphinoyl]-(2,4,6-trimethyl-3-[phenyl-(2,4,6-trimethyl-benzoyl)-phosphinoanecarbonyl]-phenyl)-methanone



Formula I, R_1 = phenyl, R_2 = mesityl, Q = mesitylene, $n=1$, $m=1$

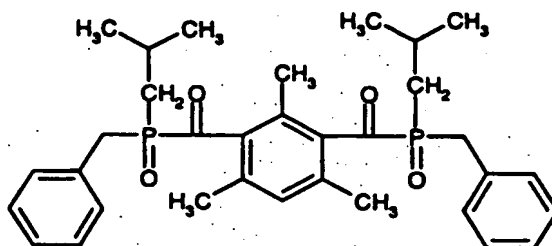
120 ml (0.191 mol) butyllithium were dropped at a temperature of -20°C to a solution of 10.0g (0.091mol) phenylphosphine in 150ml tetrahydrofuran. A Yellow suspension was obtained. Subsequently 11.2g (0.0455mol) 2,4,6-trimethylbenzoyl-1,3-dicarboxylic acid dichloride diluted with 50ml tetrahydrofuran were added dropwise at a temperature of 0°C . The reaction mixture was kept at that temperature during 30 min under stirring. Subsequently 16.6g (0.091mol) 2,4,6-trimethylbenzoylchloride were added dropwise and stirred at the same temperature for 2 hours. Subsequently the reaction mixture was allowed to reach room temperature. The solvent was rotatory evaporated. The residue is taken up in 200ml toluene. The solution was diluted with water and the layers were separated. 10.3g (0.091mol; 30%) hydrogen peroxide were added to the organic phase. After stirring for 2 h, the organic phase was washed with water and with aqueous saturated NaHCO_3 , dried over MgSO_4 and filtered. Evaporation and Flash column chromatography (eluent: Hexan/ethylacetat 3:1) gave the title compound as a yellow viscous resin. ^{31}P -NMR 8.30ppm
 ^1H -NMR (ppm) 7.72-7.80 (m), 7.45-7.47 (m), 6.76 (s), 6.62-6.67 (m), 2.11 (s), 2.05 (s), 1.96 (s) und 1.89-1.92 (d) determined in CDCl_3 .

The following BAPOs may be prepared analogously.

Ex	Product	Educt	NMR of the Product
1.a	 <p>Formula I, $R_1 = \text{phenyl}$, $R_2 = \text{mesityl}$, $Q = o\text{-phenylene}$,</p>	Phenylphosphine, Phthaloyldichloride, 2,4,6-Trimethylbenzoyl chloride.	$^{31}\text{P-NMR}$ 13.12ppm $^1\text{H-NMR}$ (ppm) 8.26-8.28 (d), 7.92-7.95 (d), 7.57-7.72 (m), 7.03-7.29 (m), 6.49 (s), 2.06 (s), and 1.60 (s) in CDCl_3 . Smp. 202-203°C
1.b	 <p>Formula I, $R_1 = \text{isobutyl}$, $R_2 = \text{mesityl}$, $Q = \text{mesitylene}$.</p>	Isobutylphosphine, 2,4,6-Trimethylbenzoyl- 1,3-dicarboxylic acid chloride, 2,4,6-Trimethylbenzoyl chloride.	$^{31}\text{P-NMR}$ 29.45ppm $^1\text{H-NMR}$ (ppm) 6.87 (s), 6.77-6.78 (d), 1.97-2.20 (m) und 0.96-0.98 (t) in CDCl_3 .
1.c	 <p>Formula I, $R_1 = \text{phenyl}$, $R_2 = \text{mesityl}$, $Q = 3,3',4,4'\text{-benzophenone-tetrayl}$.</p>	Phenylphosphine 3,3',4,4'-benzophenone tetracarboxylic acid dichloride 2,4,6-trimethylbenzoyl chloride	

2. Preparation of dimer monoacylphosphine oxide. (MAPO)

[3-(Benzyl-isobutyl-phosphinoanecarbonyl)-2,4,6-trimethyl-phenyl]-(benzyl-isobutyl-phosphinoyl)-methanone

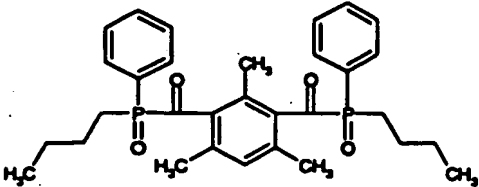
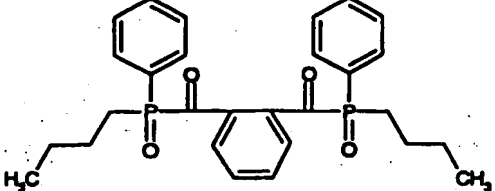
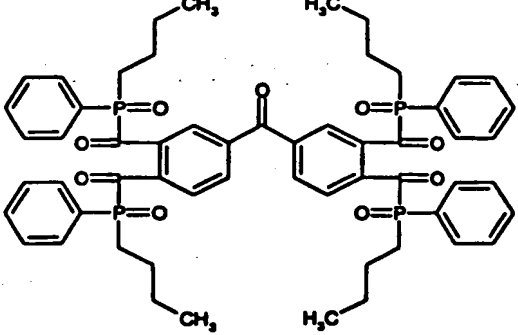


Formula II, R_1 = isobutyl, R_3 = benzyl, Q = mesitylene, $n=1$, $m=1$

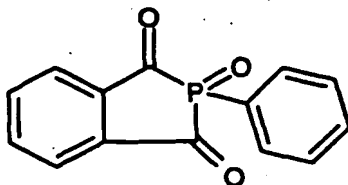
120 ml (0.191 mol) butyllithium were dropped at a temperature of -20°C to a solution of 8.2g (0.091mol) isobutylphosphine in 150ml tetrahydrofuran. Subsequently 11.2g (0.0455mol) 2,4,6-trimethylbenzoic acid dichloride diluted with 50ml tetrahydrofuran were added dropwise at a temperature of 0°C . The reaction mixture was kept at that temperature during 30 min under stirring. Subsequently 15.56g (0.091mol) benzylbromide were added dropwise and stirred at the same temperature for 2 hours. Subsequently the reaction mixture was allowed to reach room temperature. The solvent was rotatory evaporated. The residue is taken up in 200ml toluene. The solution was diluted with water and the layers were separated. 10.3g (0.091mol; 30%) hydrogen peroxide were added to the organic phase. After stirring for 2 h, the organic phase was washed with water and with aqueous saturated NaHCO_3 , dried over MgSO_4 and filtered. Evaporation and Flash column chromatography (eluent: Hexan/Ethylacetat 3:1) gave the title compound as a viscous resin. $^{31}\text{P-NMR}$ 40.04ppm

$^1\text{H-NMR}$ (ppm) 7.13-7.28 (m), 6.76 (s), 3.14-3.41 (m), 2.01-2.0 (d), 1.60-1.97 (m) und 0.89-0.95 (q) determined in CDCl_3 .

The following MAPO's may be prepared analogously.

Product	Educt
 <p>Formula II, $R_1 = n\text{-butyl}$, $R_3 = \text{phenyl}$, $Q = \text{mesitylene}$, $n=m=1$.</p>	<p>Phenylphosphine</p> <p>2,4,6-Trimethylbenzoylchloride</p> <p>n-Butylbromide</p>
 <p>Formula II, $R_1 = n\text{-butyl}$, $R_3 = \text{phenyl}$, $Q = o\text{-phenylene}$, $n=m=1$</p>	<p>Phenylphosphine</p> <p>Phthaloyldichloride</p> <p>n-Butylbromide</p>
 <p>Formula II $R_1 = n\text{-butyl}$, $R_3 = \text{phenyl}$, $Q = 3,3',4,4'\text{-benzophenone tetrayl}$ $n = 2$, $m=2$,</p>	<p>Phenylphosphine</p> <p>3,3',4,4'-benzophenone tetracarboxylic acid dichloride</p> <p>n-Butylbromide</p>

3. Preparation of cyclic bisacylphosphine oxide (BAPO)
2-oxo-2-phenyl-2,5-isophosphindole-1,3-dione



Formula VI, R1 is phenyl, U is isophthaloyl.

120 ml (0.191 mol) butyllithium were dropped at a temperature of -20°C to a solution of 10.0g (0.091mol) phenylphosphine in 150ml tetrahydrofurane. A Yellow suspension was obtained. Subsequently 18.4 g (0.091 mol) of phthalic acid chloride diluted with 50 ml tetrahydrofurane were added at a temperature of 0°C . The reaction mixture was stirred at this temperature for 30 minutes and gently warmed up to room temperature with additional stirring for 2 hours. The solvent was evaporated on a rotatory evaporator and the residue diluted with 200 ml of toluene and washed with water.

10.3 g (0.091 mol; 30%) hydrogen peroxide was added to the organic phase. After 2 hours at room temperature, the organic phase was separated, washed with water and with aqueous saturated NaHCO_3 , dried over MgSO_4 and filtered. Evaporation of the solvent and flash chromatography gave the title compound.

Application Example**Weight (g) Product Description**

30.0	Ebecryl 605	Epoxyacrylate (UCB)
10.0	Ebecryl 7100	Aminoacrylate (UCB)
5.0	Ebecryl 40	Propoxylated Pentaerythrol (UCB)
30.0	OTA 480	Acrylated trifunctional oligomer based on a glycerol derivative (UCB)
24.0	TPGDA	Tripropylene glycol diacrylate
0.5	Ebecryl 1360	Silicone hexaacrylate
0.5	Dow Corning 57	Silicone additive, Dow Corning
100.0	Total OPV Formulation	

Photoinitiators were investigated with a concentration of 10% and 8% based on 100% weight of the formulation.

For the determination of the cure speed the formulations were applied to white card boards (400µm) and exposed to the UV light of a medium pressure mercury lamp with a power output of 120W/cm. The speed of the conveyor belt at which the formulation was completely cured and track free, corresponds to the cure speed.

The results are shown in Table 1

Table 1

Substrate	white cardboard (400 µm)	
Application equipment	(Erichsen)	
Layer thickness	5 µm	
Lamps	1 m.p. Hg 120 W/cm (IST)	
<u>Cure speed (m/min)</u>	10% Photoinitiator	8% Photoinitiator
Example 1	90	50
Example 1.b	80	10
Example 2	30	15

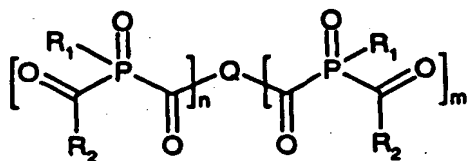
For the determination of the gloss the formulations were applied to chip boards and cured using the UV light of a medium pressure mercury lamp with a power output of 120W/cm at a conveyor belt speed of 10m/min. The gloss of the cured films was measured after the samples were post-exposed under a lamp of the type TKL 40/05 for 22 hours. The results are shown in Table 2.

Table 2**Substrate** chip boards**Layer thickness** 100 µm**Lamps** 1 m.p. Hg 120 W/cm (IST), TLK 40/05**Cure Speed** 10m/min**Equipment** gloss: Haze-Gloss (Byk-Gardner)**Gloss 20°**

	10% Photoinitiator	8% Photoinitiator
Example 1	88.00	88.00
Example 1.b	88.00	
Example 2	88.00	84.00

Claims

1. Dimer and multimer forms of BAPO compounds of the formula I



wherein

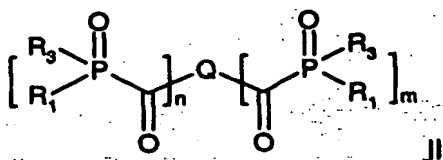
R_1 is unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

R_2 is unsubstituted or substituted C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

Q is a di-tri or tetravalent arylene residue;

n is 1-4, m is 0-2, $n+m$ is 2, 3 or 4.

2. Dimer and multimer forms of MAPO compounds of the formula II



wherein

R_1 and R_3 independently of one another are unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_6 cycloalkyl or C_5 - C_{14} aryl;

Q is a di-tri or tetravalent arylene residue;

n is 1-4, m is 0-2, $n+m$ is 2, 3 or 4;

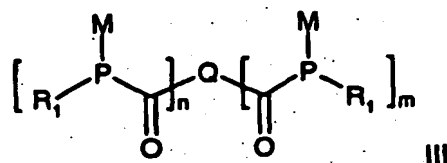
with the proviso, that R_1 and R_3 are different from each other.

3. Process for the preparation of dimer or multimer forms of BAPO compounds of the formula I and of dimer or multimer forms of MAPO compounds of the formula II, characterized in that $(n + m)$ equivalents of a dimetalated-phosphine $\text{R}_1\text{P}(\text{M})_2$ are reacted

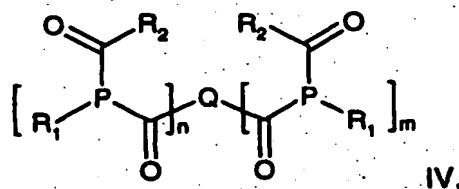
with one equivalent of a di- or polycarboxylic acid halogenide $\left[\text{Hal} - \text{C}(\text{O}) \right]_n - \text{Q} - \left[\text{C}(\text{O}) - \text{Hal} \right]_m$

to form an intermediate of the formula III

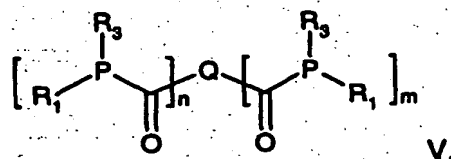
- 29 -



the intermediate is then reacted either with $(n + m)$ equivalents of a further carboxylic acid halogenide ($\text{R}_2\text{-CO-Hal}$) to form dimer or multimer forms of bisacylphosphine-intermediates of the formula IV

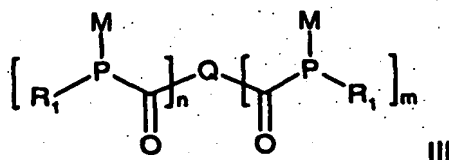


or with $(n + m)$ equivalents of a halogenide $\text{R}_3\text{-Hal}$ to form dimer or multimer forms of monoacylphosphine intermediates of the formula V,



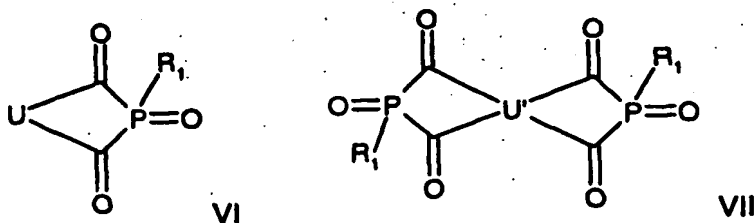
said phosphines IV or V are then oxidized to form phosphine oxides of the formula I or II; wherein M is Li, Na or K; and R_1 , R_2 and R_3 ; Q; n and m are as defined in claims 1 and 2.

4. Compounds of the formula III



wherein M, R_1 , n and m are as defined in claim 3.

5. Cyclic forms of BAPO compounds of the formula VI or VII

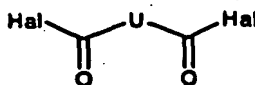


wherein

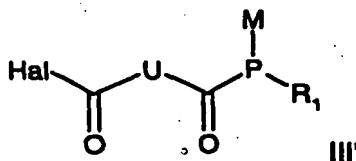
R_1 is unsubstituted or substituted C_1 - C_{12} alkyl, benzyl, C_1 - C_{12} alkoxy, C_3 - C_8 cycloalkyl or C_5 - C_{14} aryl;

U is a divalent arylene residue and U' is a tetravalent arylene residue.

6. Process for the preparation of cyclic forms of BAPO compounds of the formula VI characterized in that one equivalent of a dimetalated-phosphine $R_1P(M)_2$ are reacted with one equivalent of a dicarboxylic acid halogenide

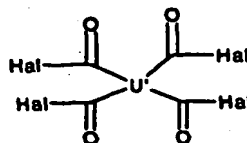


to form an intermediate of the formula III'

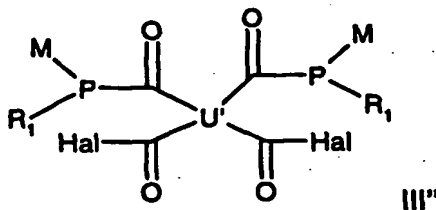


said intermediate cyclizes and is then oxidized to form phosphine oxides of the formula VI, wherein M is Li, Na or K; R_1 and U are as defined in claim 5.

7. Process for the preparation of cyclic forms of BAPO compounds of the formula VII characterized in that two equivalent of a dimetalated-phosphine $R_1P(M)_2$ is reacted with one equivalent of a tetracarboxylic acid halogenide



to form an intermediate of the formula III''



said intermediate cyclizes and is then oxidized to form phosphine oxides of the formula VII wherein M is Li, Na or K; R_1 and U' are as defined in claim 5.

8. Process according to any one of claims 3, 6 or 7, wherein M is Li and wherein the process is carried out in an inert atmosphere at a temperature from -20 to 80°C.

9. Compounds according to any one of claims 1, 2 or 4, wherein n is 1 and m is 1.

10. Photopolymerizable composition comprising

- (a) at least one ethylenically unsaturated photopolymerizable compound, and**
- (b) as photoinitiator, at least one compound of the formula I, II, VI or VII as defined above.**

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/EP 03/05801

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07F9/53 C07F9/6568 C07F9/28 C08F2/50 G03F7/029

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07F C08F G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/031898 A1 (JEAN-PIERRE WOLF) 18 October 2001 (2001-10-18) cited in the application page 55, compounds 17 and 18	1,9,10
X	EP 0 601 413 A (BASF AG) 15 June 1994 (1994-06-15) examples IA, IB	2,9,10
X	EP 0 007 508 A (BASF AG) 6 February 1980 (1980-02-06) page 10, line 25; example 5	2,9,10
X	DE 22 45 817 A (DYNAMIT NOBEL AG) 28 March 1974 (1974-03-28) examples 1-7	2,9
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *A* document member of the same patent family

Date of the actual completion of the international search

8 September 2003

Date of mailing of the international search report

26/09/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer

Beslier, L

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/05801

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BARRON A.R. ET AL.: "Cyclic carboxylic monophosphides: a new class of phosphorus heterocycle" JOURNAL OF THE CHEMICAL SOCIETY, CHEMICAL COMMUNICATIONS., no. 23, - 1 December 1987 (1987-12-01) pages 1753-1754, XP002253683 CHEMICAL SOCIETY. LETCHWORTH., GB ISSN: 0022-4936 scheme 1	5
A	EP 0 413 657 A (CIBA-GEIGY AG) 20 February 1991 (1991-02-20) the whole document	5,10
P,X	MACARIE L. ET AL.: "Tereftaloilbis (fosfonati) utilizati ca fotoinitiatori de polimerizare radicalica" REVISTA DE CHIMIE, vol. 53, no. 7, - 31 July 2002 (2002-07-31) pages 568-571, XP008021220 BUCHAREST, RO ISSN: 0034-7752 the whole document	1,9,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 03/05801

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2001031898	A1	18-10-2001	BE 1013960 A3 BR 0100910 A CA 2334291 A1 CN 1308081 A DE 10105046 A1 FR 2804683 A1 GB 2360283 A ,B IT MI20010242 A1 JP 2001270894 A NL 1017310 C2 NL 1017310 A1 US 2002107413 A1	14-01-2003 02-10-2001 08-08-2001 15-08-2001 09-08-2001 10-08-2001 19-09-2001 07-08-2002 02-10-2001 18-06-2002 09-08-2001 08-08-2002
EP 601413	A	15-06-1994	DE 4240964 A1 CA 2110631 A1 DE 59309939 D1 EP 0601413 A1 ES 2142329 T3 JP 6247992 A US 5410060 A	09-06-1994 06-06-1994 02-03-2000 15-06-1994 16-04-2000 06-09-1994 25-04-1995
EP 7508	A	06-02-1980	DE 2830927 A1 DE 2909992 A1 DE 2909994 A1 CA 1138877 A1 DE 2965566 D1 DK 171353 B1 DK 436582 A DK 436682 A ,B, EP 0007508 A2 ES 482450 A1 FI 792196 A ,B, FI 840240 A ,B, JP 1492344 C JP 55015471 A JP 63040799 B NO 792333 A NO 841028 A ,B, NO 841029 A ,B, US 4324744 A CA 1129703 A1 DE 2967111 D1 EP 0059988 A1 US 4292152 A US 4385109 A CA 1129422 A1 DE 2967264 D1 EP 0057474 A2 US 4298738 A US 4710523 A	31-01-1980 02-10-1980 02-10-1980 04-01-1983 07-07-1983 16-09-1996 01-10-1982 01-10-1982 06-02-1980 01-04-1980 15-01-1980 20-01-1984 20-04-1989 02-02-1980 12-08-1988 15-01-1980 15-01-1980 15-01-1980 13-04-1982 17-08-1982 16-08-1984 15-09-1982 29-09-1981 24-05-1983 10-08-1982 22-11-1984 11-08-1982 03-11-1981 01-12-1987
DE 2245817	A	28-03-1974	DE 2245817 A1	28-03-1974
EP 413657	A	20-02-1991	DD 298405 A5 DE 59010615 D1 EP 0413657 A2 EP 0736540 A2 ES 2098260 T3	20-02-1992 06-02-1997 20-02-1991 09-10-1996 01-05-1997

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 03/05801

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 413657	A	JP 2973130 B2	08-11-1999
		JP 3101686 A	26-04-1991
		KR 168328 B1	20-03-1999
		KR 168316 B1	30-03-1999
		RU 2071610 C1	10-01-1997
		RU 2057759 C1	10-04-1996
		US 5218009 A	08-06-1993

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☒ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.